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Screening Coriander Gene Pool for Special Uses

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Coriander (*Coriandrum sativum* L.) is an aromatic member of the Apiaceae with a wide diversity of uses (Diederichsen 1996). Its rapid life cycle allows it to fit into different growing seasons, making it possible to grow the crop under a wide range of conditions. Three subspecies and 10 botanical varieties of coriander have been proposed at the infraspecific level (Diederichsen and Hammer 2003) based on phenotypic characteristics; however, molecular evidence does not support classifications based on phenotypic and/or biochemical characteristics (López 2006).

The objectives of our study were to assess the phenotypic and biochemical characteristics of coriander germplasm collections that would make them suitable for different uses and to use amplified fragment length polymorphism (AFLP) (Vos et al. 1995) to clarify patterns of genetic diversity and its partitioning among these populations, by means of an analysis of molecular variance (AMOVA) (Excoffier et al. 1992).

MATERIALS AND METHODS

An initial characterization of morphological and phenological traits was conducted in the field in Ames, Iowa in 2002, evaluating 139 accessions of coriander germplasm obtained from the North Central Regional Plant Introduction Station (NCRPIS). A stratified sample of 60 of these accessions was subjected to a replicated field characterization with two planting dates in 2003 (Fig. 1).

In 2003 and 2004, we distilled essential oils from harvested seed samples and conducted Gas Chromatography/Mass Spectrometry analyses to characterize seeds for essential oil composition. Fatty-acid analyses were conducted in the laboratory of T. Isbell, USDA-ARS, NCAUR, Peoria, Illinois.

In 2005, seedlings of these 60 accessions were grown in the greenhouse, and DNA was extracted from 12 plants per accession. These DNA samples were combined into four, three-plant bulks for AFLP analysis. Euclidean distances (Mohammadi and Prasanna 2003) were estimated from the morphological and phenological data and genetic distances from the AFLP data. The corresponding distance matrices were subjected to cluster analyses, and AMOVA was used to assess the partitioning of genetic variation among groups defined through the cluster analyses.

In the present study, we grouped accessions by suitability of use as spices and vegetables, for high essential-oil and fatty-acid contents in their seeds, and for high linalool and petroselenic-acid yields. In this way, we

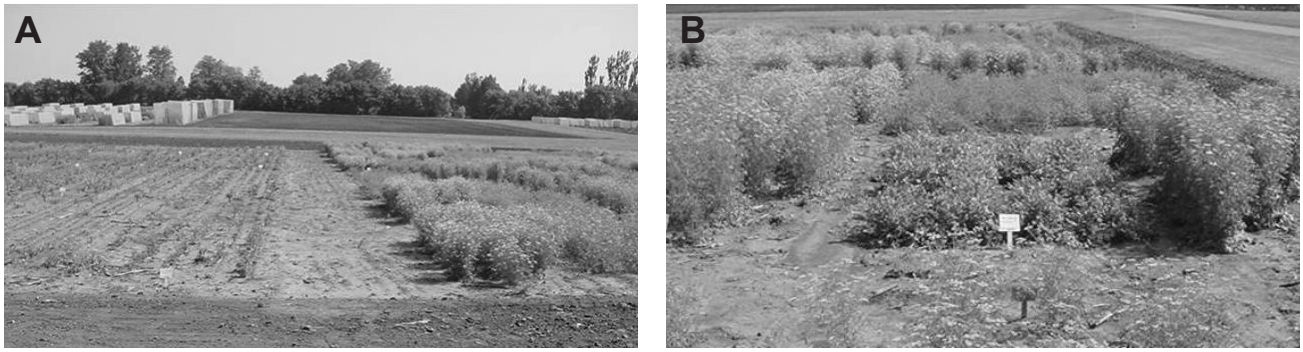

Fig. 1. 2003 field plot for phenotypic characterization of 60 coriander accessions. (A) Developmental differences under two planting dates. (B) Phenological and morphological variation among different accessions (photos by Pedro López).

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could identify accessions with the highest values of useful traits to inform users about these potential valuable genetic resources for new crop development and plant breeding.

RESULTS AND DISCUSSION

Eight accessions, characterized by their high 1000-fruit weights, may be well suited for use of their fruits as a spice (Table 1). They all exhibited a short life cycle and originated from Canada, India, Mexico, Netherlands, and Oman. Morphologically, they conform to subspecies *sativum* and *indicum* (sensu Diederichsen and Hammer 2003).

Two accessions with longer life cycles and many basal and cauline leaves (Fig. 2) may be considered suitable for use as leafy vegetables (Table 2). They originated in the Russian Federation and Syria, and they are morphologically intermediate between subspecies *indicum* and *microcarpum* (sensu Diederichsen and Hammer 2003).

Two accessions, representing subspecies *microcarpum*, displayed high overall essential-oil contents (Table 3). They were intermediate in life cycle and came from Tajikistan and Uzbekistan. These same two accessions presented the highest linalool yield per plant.

Five morphologically diverse accessions with high fatty-acid content were intermediate to late in maturity (Table 4). They came from the Republic of Georgia, Mexico, Pakistan, Tajikistan, and Turkey. The highest petroselenic-acid yields were obtained from five accessions with intermediate life cycles, from

Fig. 2. A particularly leafy coriander plant (photo by Pedro López).

Table 1. Characteristics of large-seeded coriander accessions.

Subspecies Accession	1000 fruit wt (g)	Days to flowering	No. basal leaves	Plant ht (cm)	Fruit yield (g/plant)	Essential oil content (%)	Fatty-acid content (%)	Petroselenic acid yield (g/plant)	Linalool yield (g/plant)
indicum									
Ames 23633	8.7	41.4	2.5	38.5	1.3	0.66	21.5	0.20	0.01
Ames 23639	8.6	41.6	2.3	38.2	2.0	0.53	21.3	0.29	0.01
Ames 21101	8	40.1	2.9	34.1	1.6	0.39	21.0	0.23	0.00
sativum									
Ames 18596	10.3	41.0	4.1	40.2	3.7	0.63	17.0	0.43	0.02
Ames 18587	10.0	41.6	3.5	37.6	3.8	0.45	16.1	0.41	0.01
Ames 26817	8.5	49.2	4.4	44.2	4.5	0.53	23.7	0.76	0.02
Ames 26822	8.5	47.1	5.2	44.2	7.4	0.48	21.9	1.13	0.02
Ames 26819	8.4	47.9	4.9	37.9	8.5	0.52	21.0	1.23	0.03
Mean	8.9	43.7	3.7	39.4	4.1	0.52	20.4	0.59	0.01

Table 2. Characteristics of leafy coriander accessions of an undefined subspecies.

Accession	No. basal leaves	Days to flowering	Plant ht (cm)	Fruit yield (g/plant)	1000 fruit wt (g)	Essential oil content (%)	Fatty acid content (%)	Petroselenic acid yield (g/plant)	Linalool yield (g/plant)
Ames 25696	40.8	77.3	62.6	2.3	3.9	0.18	14.9	0.20	na
Ames 21655	36.5	66.1	52.6	2.9	4.5	0.23	17.7	0.32	0.00
Mean	38.7	71.7	57.6	2.6	4.2	0.20	16.3	0.26	0.00

Mexico, the US, and Tajikistan (Table 5). Subspecies *sativum* and *microcarpum* are represented in this group.

Based on Euclidean distances from phenotypic and biochemical data and genetic distances from molecular data, seven phenotypic groups, seven biochemical groups, and four genetically-defined groups, respectively, were identified among the 60 characterized accessions (López 2006). Analysis of molecular variance (AMOVA) results for those groups on the basis of 80 polymorphic AFLP markers are shown in Table 6. Significant levels of variation among groups, among accessions within groups, and within accessions were all observed, but variation within accessions was higher than for the other two components, and, although still statistically significant, among- and within-group variation was minimal. Consistently, most of the genetic variation in coriander was found within accessions, which is consistent with an insect-pollinated, allogamous crop (Diederichsen 1996).

Table 3. Characteristics of coriander subspecies microcarpum accessions with high essential-oil content and linalool yield.

Accession	Essential-oil content (%)	Days to flowering	No. basal leaves	Plant ht (cm)	Fruit yield (g/plant)	1000 fruit wt (g)	Fatty acid content (%)	Petroselenic acid yield (g/plant)	Linalool yield (g/plant)
PI502320	1.88	60.0	10.0	53.0	7.6	4.7	20.2	1.01	0.11
Ames 13900	1.79	56.2	7.0	49.7	10.4	5.0	23.2	1.59	0.14
Mean	1.83	58.1	8.5	51.3	9.0	4.8	21.7	1.30	0.12

Table 4. Characteristics of coriander accessions with high fatty-acid content.

Subspecies Accession	Fatty-acid content (%)	Days to flowering	No. basal leaves	Plant ht (cm)	Fruit yield (g/plant)	1000 fruit wt (g)	Essential oil content (%)	Petroselenic acid yield (g/plant)	Linalool yield (g/plant)
indicum									
Ames 23620	24.3	41.6	3.4	34.4	2.2	5.4	0.39	0.37	0.01
microcarpum									
Ames 24923	24.3	51.6	10.1	48.8	3.3	3.3	0.45	0.56	0.01
PI174130	23.7	59.1	8.8	46.8	2.5	4.7	0.38	0.39	0.01
Ames 13900	23.2	56.2	7.0	49.7	10.4	5.0	1.79	1.59	0.14
sativum									
Ames 26817	23.7	49.2	4.4	44.2	4.5	8.5	0.53	0.76	0.02
Mean	23.8	51.5	6.7	44.8	4.6	5.4	0.71	0.73	0.04

Table 5. Characteristics of coriander accessions with high petroselenic-acid yield.

Subspecies Accession	Petroselenic acid yield (g/plant)	Days to flowering	No. basal leaves	Plant ht (cm)	Fruit yield (g/plant)	1000 fruit wt (g)	Essential oil content (%)	Fatty acid content (%)	Linalool yield (g/plant)
microcarpum									
Ames 13900	1.59	56.2	7.0	49.7	10.4	5.0	1.79	23.2	0.14
Ames 25169	1.45	52.8	7.4	54.7	9.2	6.1	0.73	22.5	0.05
Ames 26820	1.16	61.8	12.3	60.7	10.5	7.1	0.69	16.3	0.05
sativum									
Ames 26819	1.23	47.9	4.9	37.9	8.5	8.4	0.52	21.0	0.03
Ames 26822	1.13	47.1	5.2	44.2	7.4	8.5	0.48	21.9	0.02
Mean	1.31	53.1	7.3	49.5	9.2	7.0	0.84	21.0	0.06

Table 6. Analysis of Molecular Variance for defined groups of coriander accessions, based on 80 AFLP markers.

	Phenotypic groups		Biochemical groups		Molecular groups	
Source of variation	DF	Variation (%)	DF	Variation (%)	DF	Variation (%)
Among groups	6	3.53***	6	6.10***	3	6.71 ***
Among accessions w/groups	53	26.09***	52	24.30***	56	23.96 ***
Within accessions	180	70.38***	177	69.49***	180	69.33 ***
Total	239		235		239	

*** = $p<0.001$

CONCLUSIONS

In spite of clear differences in phenotypic and biochemical characteristics among the defined groups, an AMOVA based on AFLP data provided no clear molecular support for these groups. However, phenotypic and biochemical characterization does allow us to distinguish accessions that are more suitable for special uses; furthermore, it will now be possible to develop a practical classification for coriander germplasm maintained at the NCRPIS, based on phenotypic diversity.

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